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14. Abstract/Notes

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APPLICATION OF REMOTE SENSING DATA TO LAND USE AND LANDCOVER ASSESSMENT IN THE TUBARÃO RIVER COASTAL PLAIN, SANTA CATARINA, BRAZIL.

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ABSTRACTS

By means of aerial photography and MSS-LANDSAT data, a land use/ land cover classification was applied to the Tubarão River coastal plain. The following classes were identified: Coal related areas, permanently flooded wetlands, periodically flooded wetlands, agricultural lands, bare soils, water bodies, urban areas, forestlands.

1. INTRODUCTION

The acquisition of land use and land cover* information of a costal region is among the first steps toward a rational development planning. This information is important because these land covers occupy a transitional zone bordering land and sea, acting as a buffer to the environmental interactions between these two major divisions of the coastal ecosystem (Zenkovich, 1967). As ecotone communities between sharply changing environments, the recovery of the natural vegetation after a disturbance (burning, draining, water logging, etc) may not happen, and an erosional process takes place until another equilibrium point is reached (Tomlins and Thomson, 1980; Godfrey and Godfrey, 1974). The bordering tide affected communities are specially important as nursery niches for many of the aquatic fauna and as primary producer to the estuarine detritic food chain (Odum and Cruz, 1967; Gallagher et al. 1980; White et al. 1978).

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* *The distinction between land use and land cover is not necessary for a remote sensing problems, so they will be referred as land cover.*

In despite of the fact that the composition of these communities be relatively simple, the determination of their localization and areal extent by field methods are not an easy task due to the difficult access to some areas with extremely soft soils. Several authors report that remote sensing techniques are successfully used in coastal land cover mapping (Carter and Schubert, 1974; Gallagher, 1974; Bartlett et al. 1976). Since it presents a synoptic view of a subject area, the identification, localization and aerial extent calculation is fast and cost effective with a minimum ground checking. Some attempts have been made to extract quantitative information such as green biomass on coastal zones, by means of the vegetation reflectance characteristics in the red and infrared spectral bands (Gallagher et al, 1972; Bartlett and Klemas, 1979).

In order to evaluate the capacity of the remote sensing data available at INPE to detect coastal land cover changes, a research project proposed the analysis and comparison of the Tubarão river coastal plain's land cover in 1978 and 1981. An area of approximately 600 km^2 was chosen as study area and it encompasses the cities of Tubarão, Laguna, Jaguaruna (Fig.1).

The Tubarão river coastal plain is formed by quaternary fluvial deposits which started to accumulate when the once Tubarão bay was closed by sand spits formed by the sea, along a string of relief islands, about 25 km off the shore of the bay (Reitz, 1961; Guerra, 1950). Nowadays, the enclosed bay is mostly occupied by

marsh covered organic soils with an average level of 2 m. A few remaining water bodies are present on the coastal plain. Marine terraces are present in the South of the Garopaba lagoon and a fluvial terrace is noticed near the Tubarão river mouth. Granitic outcrops divide the coastal plain in an inselberg like way with height ranging from 20 m to more than 400 m.

The recent history of this coastal plain presents many strong environmental disturbances, mainly on water quality and availability. As consequence, agricultural areas are substituted by natural veget ation in some places while the opposite may be happening somewhere else. Total vegetation deterioration occurs in places of severe water quality impact.

A brief description of the main environmental disturbance on this area is presented below:

- From 1964 to 1978, pyrite-rich coal refuse was deposited in the Northern part of the Estiva marsh field. A large area of totally killed and heavily damaged marsh lays along the acid drainage.
- By 1980 this pyrite-rich spoil began to be explored by a pyrite concentration plant. The area of vegetation damaged by the acid drainage encroached while a new carbonous refuse site was built damaging another place downslope.
- The Camacho lagoon outlet, closed by the time, was artificial ly opened to drain a large amount of trapped waters on the

Garopaba area when the Tubarão river had a great flood in 1974. Natural sand deposition completely closed it by 1980.

- The Tubarão river, which used to meander across the plain, was straightened and lowered to prevent such major floods. This work was mostly accomplished by 1980.
- New agricultural areas on former wetlands are rather frequently installed, wherever investments are made on constructing ditches and drainage channels. Agricultural areas are also abandoned because of soil impoverishment, rise of the water table and silting of the drainage network.

As this paper will present the results from the 1978 analysis, its objective is to map the land cover of the study area by means of the available remote sensing data and to evaluate the results qualitatively.

2. METHODOLOGY

2.1 - Materials

In the development of this research it was used:

- A set of 52 color infrared (CIR) aerial photographies at the scale of 1:45,000, with longitudinal overlap of 60% and lateral overlap of 30%, obtained in August/September of 1978;

- MSS LANDSAT data CCT (path/row annotation 178/32 from April 24, 1978) with digitized information of the spectral radiance measured at every 57 x 79 m picture element in four spectral bands:

.5 -.6 μm, .6-.7 μm, .7-.8μm, .8-1.1 μm.

- DF Vasconcelos pocket stereoscope with 2 x magnification power;
- INPE's Multispectral Image Analyzer System - Image-100 (I-100) with its own hardware for image processing;
- The following software for digital image processing developed at INPE:
  - MEDIA K - An unsupervised K-means classification algorithm (Dutra et al.,.unpublished)
  - MAXVER - A maximum likelihood decision rule based supervised classification algorithm. (Velasco et. al., 1979)

2.2 - Methods

A) Air photography analysis.

A classification system based on Anderson et al, 1976 and Cowardin, 1982,was built in order to hierarchically organize the land cover classes observed on aerial photographies. The classes were characteryzed by their tone, texture, context and, specially for man made classes, size and shape. Some of the classes were named based on the photointerpreter experience while some others were kept in a descriptive form until a ground check was made. The classes obtained by this procedure will be mentioned as information classes.

Land cover classes as well as drainage networks, roads and main reliefs were outlined on a sheet of poliester for each aerial photography. The poliester sheets were set together with the aid of a

topographic map, but without the sufficient number of ground control points to be considered as a semi-controlled map. Two final products were obtained: a map describing the land cover patterns and the main roads and another with the drainage features and the borders of the relief forms.

B) MSS-LANDSAT data analysis

The below described procedures were interactively evaluated at the I-100 TV monitor at the scale of 1:104,100. The intermediate results were hard copyed as print-outs at the same scale of the photo mosaic.

As many of the classes obtained from the aerial photographies were identified from context clues, MSS-LANDSAT data classification approach avoided to use the ground truth map as the unique information source for the training phase. Spectral information was extracted from LANDSAT data themselves using an unsupervised classification algorithm, the MEDIA-K algorithm, which allowed to divide the image into 8 spectrally homogeneous classes. Using the aerial photography derived map as ground truth, each spectral class was analyzed separately.

As each of the spectral classes represented two or more third level information classes, the MAXVER algorithm was used in an attempt to subdivide them. The training samples for the MAXVER algorithm were chosen in places where the information classes presented a spectrally homogeneous classification. The hard-copy of this

procedure, with 18 classes, was again checked against the ground truth map. It was noticed that many hierarchically superior information classes could be represented by the addition of two or three of the obtained classes. Most of the final classes were thus obtained by the addition of the former procedure's class samples, except for the bare soil class, which was kept as three separate spectral classes represented under a single color display or print--out symbol, due to its intrinsic spectral differences as consequence of soil origin and water status.

The final MSS- LANDSAT data classification out-put was checked against the ground truth map in order to qualitatively evaluate the performance of the developed image classifier.

3. RESULTS AND DISCUSSIONS

3.1 - Classification system:

The classification system (Table 1) was hierarchically built so that it could be applied to both aerial photography and MSS-LANDSAT data (Anderson et al., 1976). A brief comment will be made about those classes which need an explanation to better define the classification system.

The coal related class was established as a first level class because of its importance as land cover change agent. The detailed subdivision of this class is due to the differential pollution potentials of its categories as well as to the differential MSS.LANDSAT identification capability for these categories, according

to their spectral characteristics and the presence of water.

An approach, closer to the classification system, proposed by Cowardin, 1982,was applied to the wetland class. The water regime of the area was the main criteria for the level II subdivision. Fortunately, the MSS-LANDSAT infrared channels work out very accordingly to this approach. The *Typha dominguensis* is frequently found in the wettest parts of the coastal plain, except near the Santo Antonio lagoon, where the salinity reaches higher concentrations, and the *Typha dominguensis* is substituted by *Spartina sp.* stands. On the sandy marine deposits, along the shore, depressions between deposition rills are occupied by fresh or brackish water marshes named by beach hydrosere. It corresponds to the "Etapa paludosa" of the Reitz's description (Reitz, 1961). The coal stressed vegetation class presents acid damaged plants ranging from totally killed to heavily chlorotic stands (Murtha, 1976). The floating hidrosere is composed mostly by *Eichornia sp.* The pure sedge class, represented mostly by *Scyrpus giganteous* stands can cover large periodically flooded areas. However, it is present on drier soils which are covered by pastures, after the original stand is burned. The under MSS-LANDSAT resolution mosaic, formed by irregular fire and the fast recovery of *S. giganteous* was categorized as sedge plus pasture class. The Estiva march class is originally height dominated by an non-identified Compositae. Frequent slash and burn turns it into a grass covered meadow which is quickly substituted by a Cyperaceae Juncaceae community.

The drained pasture lands, sometimes with cultivated species such as *Brachiaria sp* and *Setaria sp*, have their water regime artificially controlled. The frequently flooded pasture lands occupy once *S. giganteous* dominated areas and are periodically burned to avoide the regrowth of the original community. The meadows, periodically flooded, are composed by a very diverse herb community. Burning is not frequent on this class.

The "jundu" class is the fixed dunes vegetation dominated, at the study area, by the fire-resistant *Butia capitata* and a large variety of shrubs, mostly Myrtaceae. The moving dunes communities are stands of xeromorphic herbs and grasses occupying the between-dune spaces or even pioneering the dunes themselves.

3.2 - Ground truth map

The ground truth map, obtained from the air photographies analysis, is presented on Figure 2. Land cover patches, smaller than four MSS-LANDSAT picture elements, were not represented unless their contrast against the surroundings was very high.

3.3 - MSS-LANDSAT derived map

The final product of the MSS-LANDSAT data classification presented eight classes, i.e., coal related areas, permanently flooded wetlands, periodically flooded wetlands, vegetated agricultural lands, bare soils, water bodies, urban areas and forestlands. An alphanumerical representation

of these classes can be seen at Figure 3. The performance of each class is given below:

. Coal related areas: all but one of the level III classes were identified on the MSS-LANDSAT map, correctly positioned and with borders very similar to the actual. The ash slurry ponds were ommited for the permanently flooded wetland class. Shallow waters were commissioned into the coal related class and this is observed along the shores of the lagoons.

. Permanently flooded wetlands: a few commissions of relief shadowed areas as well as the ash slurry ponds were only erros revealed by this class.

. Periodically flooded wetlands: all of the pure stands of *S. giganteous* were ommited from this class to the vegetated agricultural lands. As one of the main MSS- LANDSAT features used to discriminate the wetland classes was the antagonic response of green biomass and water on the infrared channels, the complete cover provided by the dense, 2-3m tall *S. giganteous* canopy, hide the water and moves this class' spectral signature into drier vegetated classes decision space. The other two classes were satisfactory. This class also presented full commission of the frequently flooded pasturelands.

. Vegetated agricultural areas: unfornately the discrimination of the main agricultural land uses of the study area,rice fields and pasturelands was very difficult for the utilized date. In April the

rice fields are harvested and the green parts are being grazed by cattles. After several failed attempts to separate these classes with the interactive algorithm MAXVER, they were considered as a single class which included the others class (corn, cassava, vegetables, etc). Visually this class has the lowest ommission error, but commissioned areas of microtextured mixed unvegetated and vegetated classes and all the jundu area.

. Bare soils: the multimodal distribution of this class' intensity histogram for any of the MSS-LANDSAT channels, makes necessary the subdivision of the class. The color of bare soil fields on a false color infrared composite simulation on the I-100 TV monitor ranged from black, dark green, ..., green, ..., light green and white. The white fields were associated with the marine formations near the city of Jaguaruna. The others are known as peat soils with varying organic matter content and were divided arbitrarilly into two classes. They were added into a single class for color representation of the I-100 system (maximum of eight colors). A classical confusion between this class and urban areas class is present and can be seen in the South of Tubarão city. Dark soils were also omitted for wetland classes.

. Water: Due to the characteristically dark tonality of the water response on the MSS-LANDSAT infrared channels in contrast to the brighter land classes, the mapping of the water bodies was sucessful for all lagoons larger than 5 ha. The tide influenced lagoon shores were frequently omitted for coal related class.

.Urban areas: the larger urban segments were reasonably mapped, but the urban fringe areas as well as the settlements along the main roads were mostly omitted for the soil and vegetated agricultural lands classes, respectively.

. Forestlands: The absence of large stands of forests in the study area hampered the image sampling and good spectral characterization of this class. The results identified only those forest stands on sunny slopes of the rock outcrops. The partial soil cover of the "jundu" community is the reason for its classification as agricultural lands.

4. CONCLUSIONS

The MSS-LANDSAT derived classes presented varying identification performance and, of course, varying information reliability. For non-vegetated classes, coal related areas and waterbodies are, except for specific errors, accurately described. The sand dunes and beach area can be described by the unclassified stripe bordering the ocean in the print-out. One can rely only on the main cities cores description by the urban areas class. The same applies to the bare soil class which worked out well only on large ploughted fields. The worst performance was noted on the forestlands class. The other three vegetated classes have a fairly good classification accuracy and many of the wetlands' level III classes can be obtained if the map product is stratified into environmental units such as marine deposits, fluvial deposits, etc., and analyzed by strata (Pettinger, 1980).

Orbital remote sensing data have a level I discrimination capability, ocasionally allowing a level II detailing. The information obtained in this work reaches some level II details. They can be a first step toward many unknown information such as agricultural land use pattern and orientation, carrying capacity determination, water table level zoning, mosquito breeding sites localization (Cibula, 1976), and detritic sources for the estuarine food chain.

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TABLE 1 - CLASSIFICATION SYSTEM

1. Coal related areas

    1.1 - Deposits

        1.1.1 - Pyrite-rich coal refuse

        1.1.2 - Coal

        1.1.3 - Pyrite concentrate

        1.1v4 - Carbonous refuse

    1.2 - Slurry ponds

        1.2.1 - Pyrite fine materials

        1.2.2 - Ashes

        1.2.3 - Carbonous fine materials

2. Wetlands

    2.1 - Permanently flooded

        2.1.1 - Typha dominguensis

        2.1.2 - Spartina sp

        2.1.3 - Beach hidrosere

        2.1.4 - Stressed vegetation

        2.1.5 - floating hidrosere

    2.2 - Periodically flooded

        2.2.1 - Sedges plus pastures

        2.2.2 - Pure sedges

        2.2.3 - Estiva marsh

3 - Agricultural lands

3.1 - Rice

3.2 - Pastures

3.2.1 - Drained pastures

3.2.2 - Frequently flooded pastures

3.2.3 - Periodically flooded pastures

3.2.4 - Upland pastures

3.3 - Bare soils

3.3.1 - Organic - humid

3.3.2 - Organic - dry

3.3.3 - Sandy

3.4 - Others

4. Water bodies

4.1 - Lagoon

4.2 - Ocean

4.3 - Shallow waters

5. Urban areas

5.1 - Residential

5.2 - Allotments

5.3 - Industrial

6. Forestlands

   6.1 - Reforestation

   6.2 - Natural forests

   6.3 - Forested wetlands

   6.4 - "jundu"

7. Beach

   7.1 - Beaches and dunes

   7.2 - Between dunes vegetation

FIGURE LEGENDS

FIGURE 1 - Study area

	fluvial sediments		Sand dunes and beaches
	marine sediments		water
	rock outcrops		urban areas

FIGURE 2 - Ground truth map

FIGURE 3 - MSS-LANDSAT derived map

¤ - coal related areas

θ - permanently flooded wetlands

ß - periodically flooded wetlands

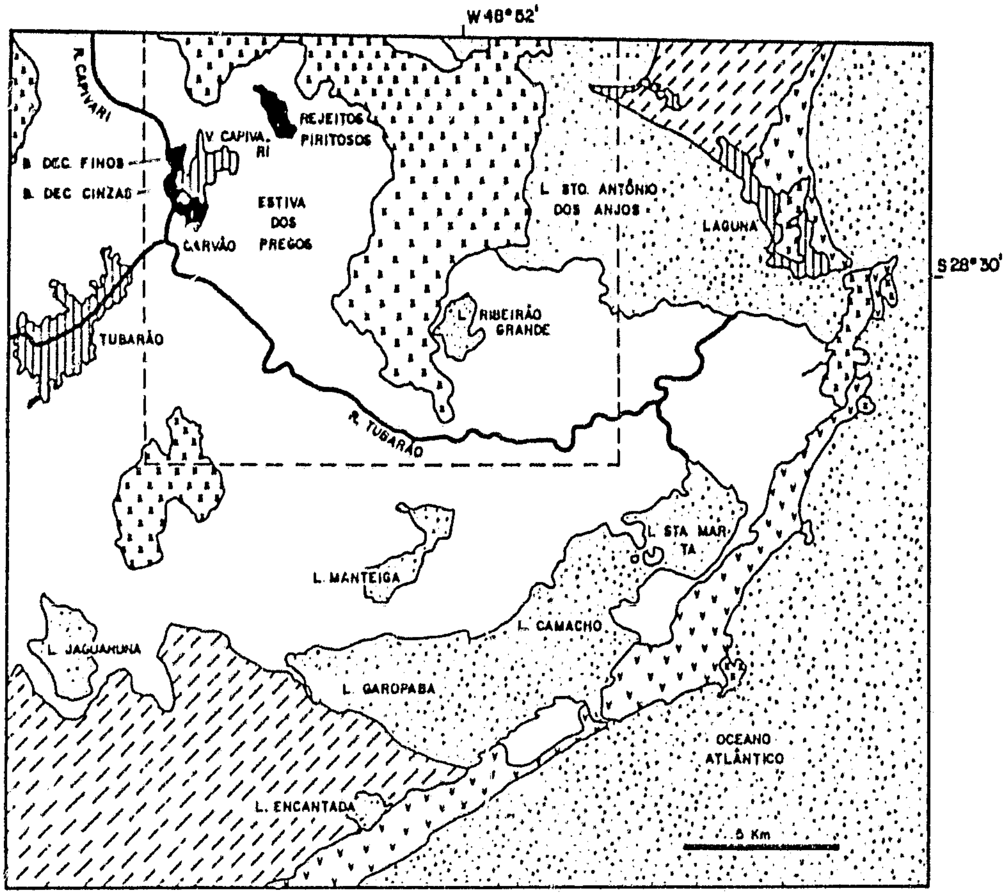
O - vegetated agricultural lands

\+ - bare soils

. - water bodies

w - urban areas

θ - forestlands



fluvial sediments

Sand dunes and beaches

marine sediments

water

rock outcrops

urban areas

Figure 1 - Study area

Figure 2 - Ground truth maps.

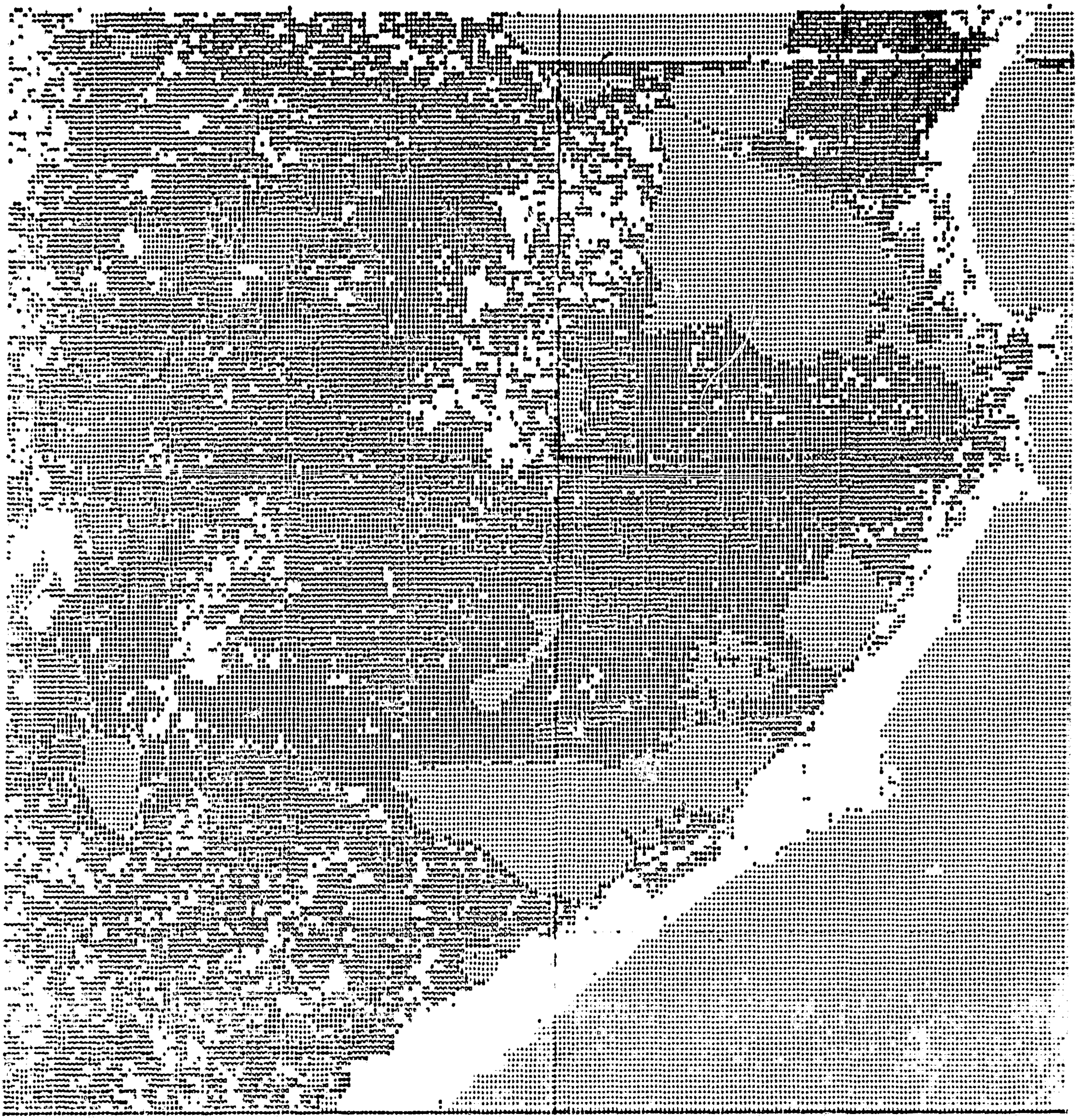


Figure 3 - MSS-LANDSAT derived map.